

# **Banana Production in Greenhouses**

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## **Executive Summary**

Bananas are an incredibly important economic crop. They are traditionally grown in tropical plantations and are threatened by several incredibly deadly fungi. Production in greenhouses would allow northern climates to grow bananas much closer and could provide a certain amount of protection against these pathogens.

## **I. Introduction**

### **A. Study Species**

Bananas, *Musa acuminata* Colla, are a very important domesticated herbaceous food crop to the world. It has been adopted in every region of the world that it can grow. It would be very beneficial to nontropical climates, such as Minnesota, to be able to grow bananas in greenhouses in these places. It could potentially drastically cut transportation costs while also providing better disease control over bananas. There are already plenty of Minnesota-grown greenhouse crops, like tomatoes, that could possibly be intercropped with bananas. Also, growing locally sourced bananas would cater to a population of people willing to spend extra money.

### **B. Taxonomic Classification**

There are several different species of bananas that are cultivated today, all of which belong to the family Musaceae, and the genus *Musa*. The most commonly cultivated one (the one that is found in grocery stores) is the Cavendish cultivar. This banana, *Musa acuminata*, makes up 95% of all banana sales in North America (Koeppel 2010). Although none of them are nearly as popular as Cavendish, there are of course many other cultivars produced. The 'Lady Finger' and 'Orito' varieties are much shorter and stubbier. There are also the 'Apple' Bananas, 'Pisang Raja', 'Red' and 'Plantains', the last of which actually belong to the species *M. paradisiaca* and are much starchier and less sweet than the other bananas (Nsabimana 2014). Excluding the starchy Plantains, the other cultivars are all considered 'dessert bananas' which just means they are sweeter and softer.

### **C. Physical Description**

Despite slight differences in the fruit size and color, all the bananas share the same general characteristics. Contrary to popular belief, banana plants are not trees. Since they are monocots, bananas are simply large perennial herbaceous plants with apparent trunks (FAO). The leaves roll slightly and overlap each other, forming 'trunks.' These leaves are very large and slightly waxy. The plant can spread via rhizomes, which is important in the propagation of these plants. To 'make' a new banana plant, a piece of the rhizome is broken off and re-planted (Vezina 2015).

The flowers form on the true stem. The female ones form first, and in most propagated varieties, these develop into fruit without needing to be pollinated. The fruit clusters are called 'bunches' and in each bunch, there are separate 'hands.' Each separate banana is called a 'finger.' The fruits are typically long, and narrow, covered in a skin that is green when unripe and can range from yellow to red to brown when ripe. The edible fruit parts are white and, depending on the cultivar, may contain tiny seeds. After the growing season, which is about nine months long, the herbaceous parts of the fruit dieback and suckers sprout from the rhizome (Vezina 2015).

Banana plants are propagated vegetatively by rhizome cuttings. They need temperatures between 25-30° C. They can grow in hotter temperatures, providing they are given extra water, and they can survive in temperatures down to 14° C. Any colder and they seriously start to suffer. They also need lots of water, high humidity, and rich, fertile soil. They also prefer a more sheltered environment to protect them from high winds and prevent them

from getting tattered leaves. Depending on the location, bananas can grow all year round (Bradtke 2007).

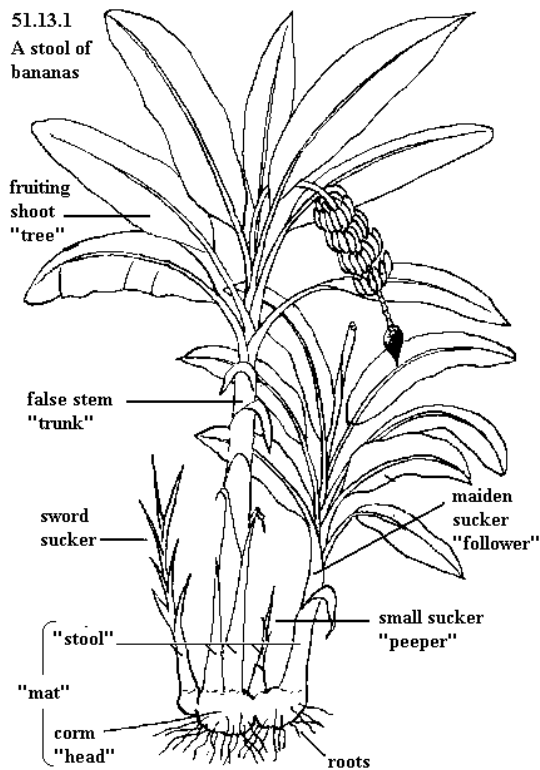


Fig. 1: Pictorial of banana anatomy and growth (Elfick 2013).

#### D. Geographic Distribution

Before being domesticated, most of 'dessert' bananas are native to the Indo-Malaysian region and stretching south to New Zealand and Northern Australia, while Plantains are native to Eastern Africa. One important species of wild banana used in breeding, *M. balbisiana*, is native to Southern Asia and the East Indies. It's not very desirable for eating due to high seed counts, but it has high disease resistance (Morton 1987).

Current distribution essentially includes all humid tropical regions, including Central and South America as well as the indigenous locations. The majority of banana production is done by Latin America, with Southeast Asia coming in second and Africa as third.

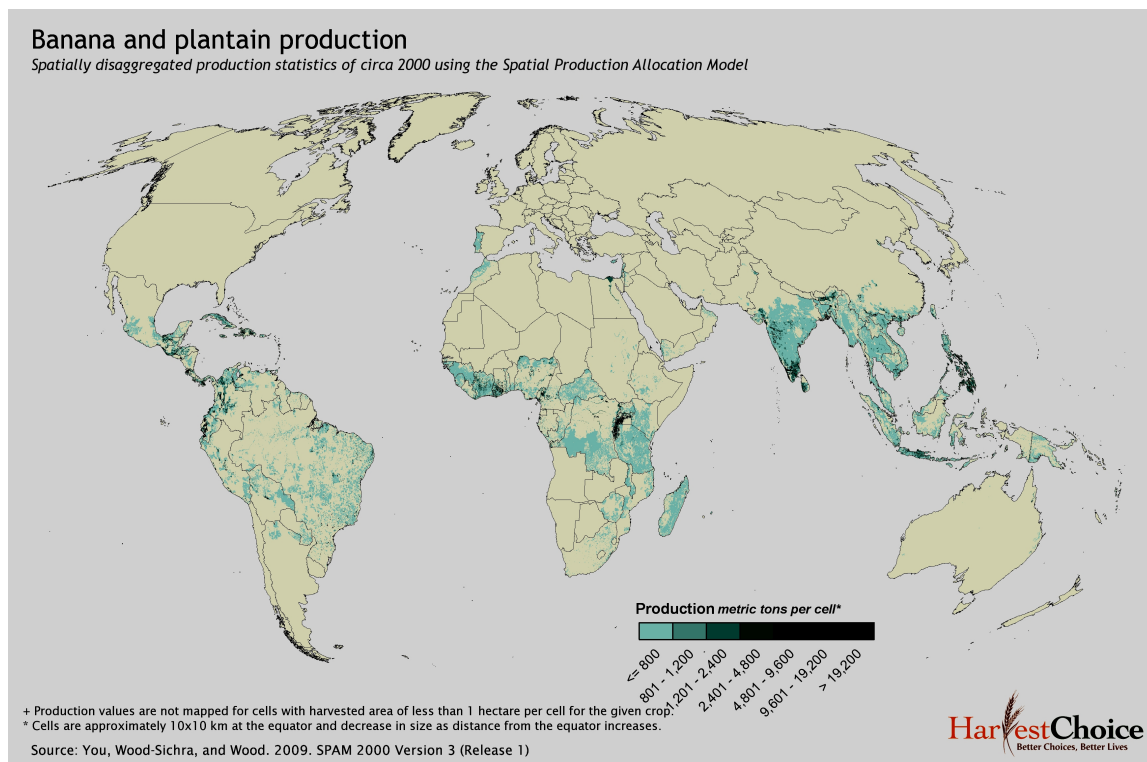


Figure 2: Geographic distribution of banana and plantain production (Guarino 2010)

## II. Crop History

### A. Domestication

Up until the 10<sup>th</sup> century A.D., the ‘dessert’ bananas were only found in the Indo-Malaysian region and stretching south to New Zealand and Northern Australia. From Asia, Middle Eastern traders around 650 AD brought the banana over to Africa (Koeppel 2008). They also spread via 10<sup>th</sup> century European explorers back to Europe (Morton 1987). By the 16<sup>th</sup>

century, they made it to South America. Of course, this doesn't mean they weren't bred and cultivated until the 16<sup>th</sup> century. The earliest known record of cultivated bananas is 3<sup>rd</sup> century AD in China. In the 1200s, the Japanese would use the fibers of certain cultivars for making fabric. But it wasn't until the 1800s that bananas were cultivated in large plantations (De Langhe 1995).

Since ancient wild bananas were inedible due to all the seeds, it is likely that the first cultivated bananas were grown for the edible corms. From there, the inedible fruits gradually mutated. Eventually, the bananas morphed into the varied edible yellow fruits that we know today, and the corms stopped being an element of great food importance (Koeppel 2008).

The history of domesticated plantation-grown banana plants is wrought with disease. Because of the heavy monoculture and the fact that the plants are clones of each other, by the 1950s, the first majorly produced banana cultivar, the 'Gros Michel', was virtually wiped out by the two major banana pathogens: Black Sigatoka and *Fusarium* (also known as Panama Disease)(Ploetz 2001). Fungicides can be used to control Sigatoka and researchers developed a cultivar that appeared to be immune to *Fusarium*, called the 'Cavendish'. As such, the market smoothly switched from 'Gros Michel' to 'Cavendish'. However, just as plants evolve, so do fungi. A new strain of *Fusarium* that affects 'Cavendish' evolved. It is found in nearly every region of banana growing, except Central America. To help prevent its spread into this region, imported vegetative material is held under quarantine. However, it's generally accepted that it's only a matter of time before it spreads across the globe (Koeppel 2008).

## **B. Uses**

The most common use of bananas in North American and European culture is as food. This especially includes the 'dessert' bananas, which are the sweeter varieties like the popular 'Cavendish' and the less-popular, much smaller 'Orito' and are primarily consumed fresh. The other kinds are the cooking bananas, which include plantains (Koeppel 2010). These are commonly consumed in Latin America and parts of Asia and Africa. Some cultures dry the unripe plantains and grind them into flour. In times of struggle, the corms can be used as a fibrous root vegetable. Other cultures use the banana root as a medicine to make the birthing process faster and for easing neck pain. Some countries also use banana leaves in cooking by wrapping them around rice, egg and spices, similar to cooking tamales. And of course, if people can make alcohol out of something, they will. Bananas are no exception. Many cultures make banana wine and beer (Nsabimana, 2014).

## **C. Supply Chain**

As pictured in the following chart, the supply chain for bananas is fairly straightforward. There are three major corporations that grow bananas: Dole, Chiquita and Del Monte (Koeppel 2008). These companies often hire local villagers as their laborers. From there, the fruit gets sent to a packaging facility where it's cleaned, sorted and packaged. It's then shipped, often overseas, to wholesalers. From these wholesalers, the bananas are sent to individual retailers where they are then purchased by the consumers.



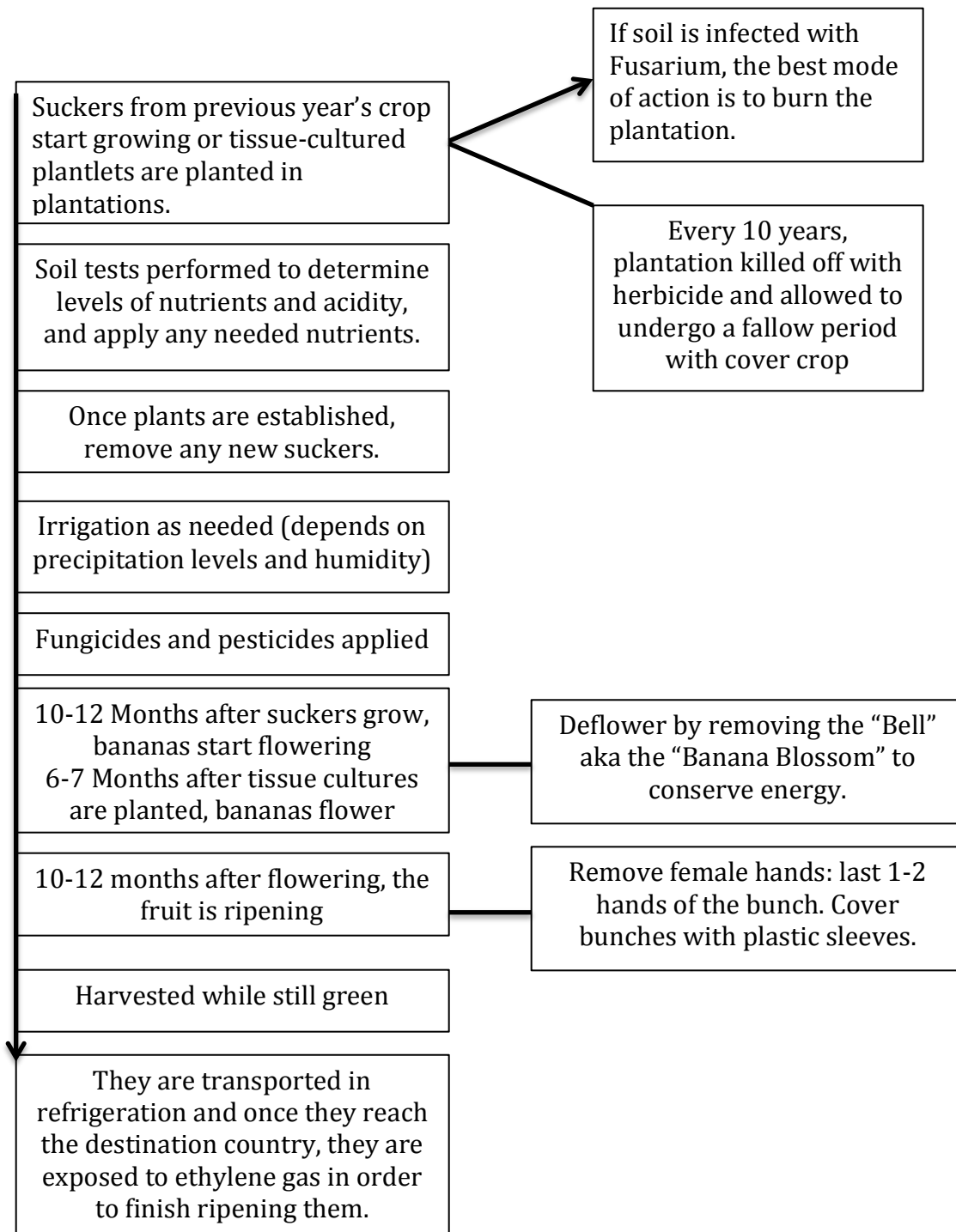
Fig. 3: Supply Chain of banana production



### III. Production Information

#### A. Current Production Practices

**Fig. 4: Crop Production Schedule for Bananas**



The vast majority of all bananas are grown on tropical plantations. Since cultivated bananas don't have seeds, they have to be grown vegetatively. Producers have two main options for planting stock. They can either use suckers from previous crop banana plants, or they can use tissue-cultured plantlets. It's a bit more risky to use the suckers, since these are more likely to be contaminated with diseases, whereas the tissue-cultured plantlets are guaranteed to be pathogen-free. In addition, it takes longer for the suckers to reach flowering (BananaPlanters 2009).

As with any other crop, it's also important to maintain proper nutrient levels. To gain the most out of the fruit, it's extra important to ensure there aren't any deficiencies in potassium (Hongwei 2004).

Since diseases are a major concern with banana production, one method of control is to implement a rotation. Every ten years, the plantation is moved and allowed to lay fallow or have an alternate cover crop. This helps diminish the presence of diseases, including Black Sigatoka and Fusarium. There are also fungicides that can be used, but many of them are incredibly toxic to other organisms (Ploetz 2001).

Once plants are established, there are multiple different methods used to help encourage the best fruit. One is to remove any extra suckers. These sap nutrients from the main plant (BananaPlanters 2009). Another is to remove the oversized secondary flower at the base of the bunch as well as the bottom 1-2 hands from the bunch. This encourages upper hands to grow longer and fuller. Fruits are also often covered in blue plastic bags (sometimes filled with pesticide) in order to protect the fruit from sunburn, diseases, and insects, as well as increasing temperature to speed up maturity (BananaPlanters 2009). Occasionally,

the bananas will need to be staked with bamboo. The bananas are then harvested before being fully ripe to aid in transportation. They are usually exported to different countries, so it's important that they are refrigerated to delay over ripening. Once they reach the destined country, the bananas are exposed to ethylene in order to continue ripening, so the fruits look good in the store (Koeppel 2008).

## **B. Current Production Statistics**

There are three main regions of the world that produce bananas for export. These are Africa, Asia and Latin America (including the Caribbean). Out of these, Latin America has, by far, the greatest percentage of exports. In 2014, total world exports of bananas equaled \$11 billion. Latin American exports accounted for \$6.2 billion dollars, which was roughly 55% of world banana exports (Workman 2015). Second place goes to Asia at 25.6%, while Africa has only 3.9%. The rest of the world's exports are distributed between countries like the United States and areas of Europe such as Spain (FAO 2014). Africa's exports are so low (despite being one of the world's top producers) because, for the most part, the bananas are distributed locally (Potts et. al 2014).

The top individual producing countries as of 2009 are India, the Phillipines, China, Ecuador and Brazil (Evans 2012). However, being the top producers doesn't equal being the top exporters.

As far as importing, Europe as a whole (except Russia) has the highest percentage at 27% (Figure 4). This amounted to 4,488 thousand tons in 2012 (FAO 2014). The close second highest importer was the United States at 4,350 thousand tons. These two groups of importers took up the vast majority of the market. A distant third ranked importer was

Russia at 8%/1,254 thousand tons. Fourth is Japan at 7 percent/1,086 thousand tons (Figure 3) (FAO 2014).

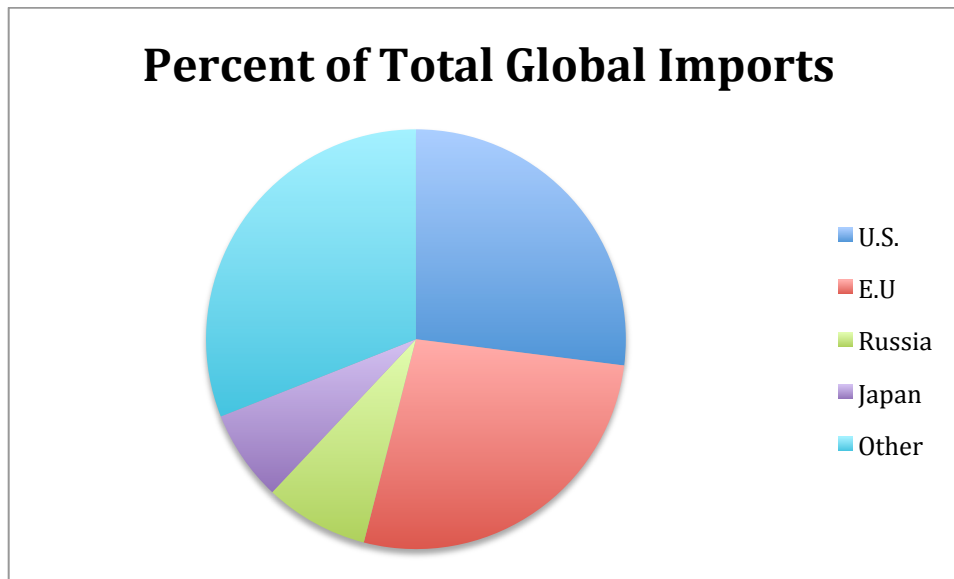


Figure 5: Percent of Total Global Imports of Bananas (FAO 2014)

The U.S. imports the majority of their bananas (28%) from Guatemala. Ecuador comes in second at 24% and Costa Rica accounts for 21% of the exports to the United States. The rest are supplied by the Honduras, Dominican Republic and Columbia (Evans 2012).

Europe also gets most of their bananas from Central America, but they also get some from Africa and parts of Europe, like Spain.

While there are an incredible number of different banana cultivars, very few are actually well-known amongst the general public. The number one cultivar is 'Cavendish'. Other prominent cultivars are Plantains (a starchy cultivar for cooking), the 'Lady Finger' (one of the smallest sweet bananas) and the 'Red' (a quick-growing, disease-resistant, small, sweet red banana) (Morton 1987).

It is very likely that sometime in the future the Cavendish bananas will be phased out due to diseases and replaced by an alternative cultivar. When breeding, researchers look to the wild banana *Musa bulbisiana*, which has great disease resistance (Morton 1987). There is already some pressure on breeders to quickly develop a new, desirable cultivar, similar to the Cavendish, due to the increasing instances of *Fusarium*.

#### **IV. Proposed Crop Transformation**

##### **A. Crop Production Changes for the Future**

Since the Cavendish banana is at risk of being wiped out by disease in field production, it would be worthwhile to start greenhouse production. If grown in greenhouses in northern climates, such as Minnesota, there would be much greater control over what goes in and out of the greenhouse system. It would also be much easier to control disease presence in the soil. If planted in pots, the soil could easily be sterilized before planting and if the plant source is sterile (as it should be), it would be far less likely to have an outbreak of *Fusarium* or Black Sigatoka. Also, with a growing insistence for local food, growing bananas in Minnesota would cater towards a market of people who would pay extra for locally grown bananas. Once 'Cavendish' are phased out of plantation production, people who want to continue eating the banana cultivar they are accustomed to will also pay extra for greenhouse-grown 'Cavendish' bananas. It would also make sense to intercrop with more interesting cultivars of bananas like 'Lady Finger' or 'Red.' These would add an extra dimension to the market.

Of course, since bananas are tropical plants, it would be absolutely crucial to maintain proper heat and humidity, especially in winter. This could be done with regular Northern greenhouse practices such as orienting the houses east-west so that one long side is facing south. The frames can be painted black to increase heat absorbency (Cura 2013). The glass can be glazed with polycarbonate for extra strength and double layered with air as insulation. In addition, narrow solar panels could be installed along the roof periodically to help contribute to the electricity. Since bananas prefer growing in a partially shady forest environment, the solar panels won't detract from the banana growth (Bradtke 2007). There should also be ventilation systems in place for the middle of summer to prevent the greenhouses from getting too hot. Automatic watering should be in place because bananas would easily dry out. To conserve water, there could be drains in the floor leading to a filtration system that would sanitize the water and recycle it back.

Since bananas are tall and not easily reached, it might be prudent to install rolling ladders and plant the bananas in rows so harvesters can easily slide from plant to plant and make harvesting much quicker and easier, or to perform maintenance on higher parts of the plant. Other options would be to use dwarf cultivars such as 'Dwarf Cavendish,' 'Dwarf Red,' or 'Dwarf Apple.' These all generally only grow between 6-10 feet tall, in comparison to the "standard" cultivars that can be 15-20 feet tall (Kepler 2009). Fog systems would also have to be available to help keep the relative humidity high.

## **B. New Banana Production Schedule**

The main alteration between current banana production and the proposed production is that bananas will be able to be grown year-round in northern, otherwise uninhabitable,

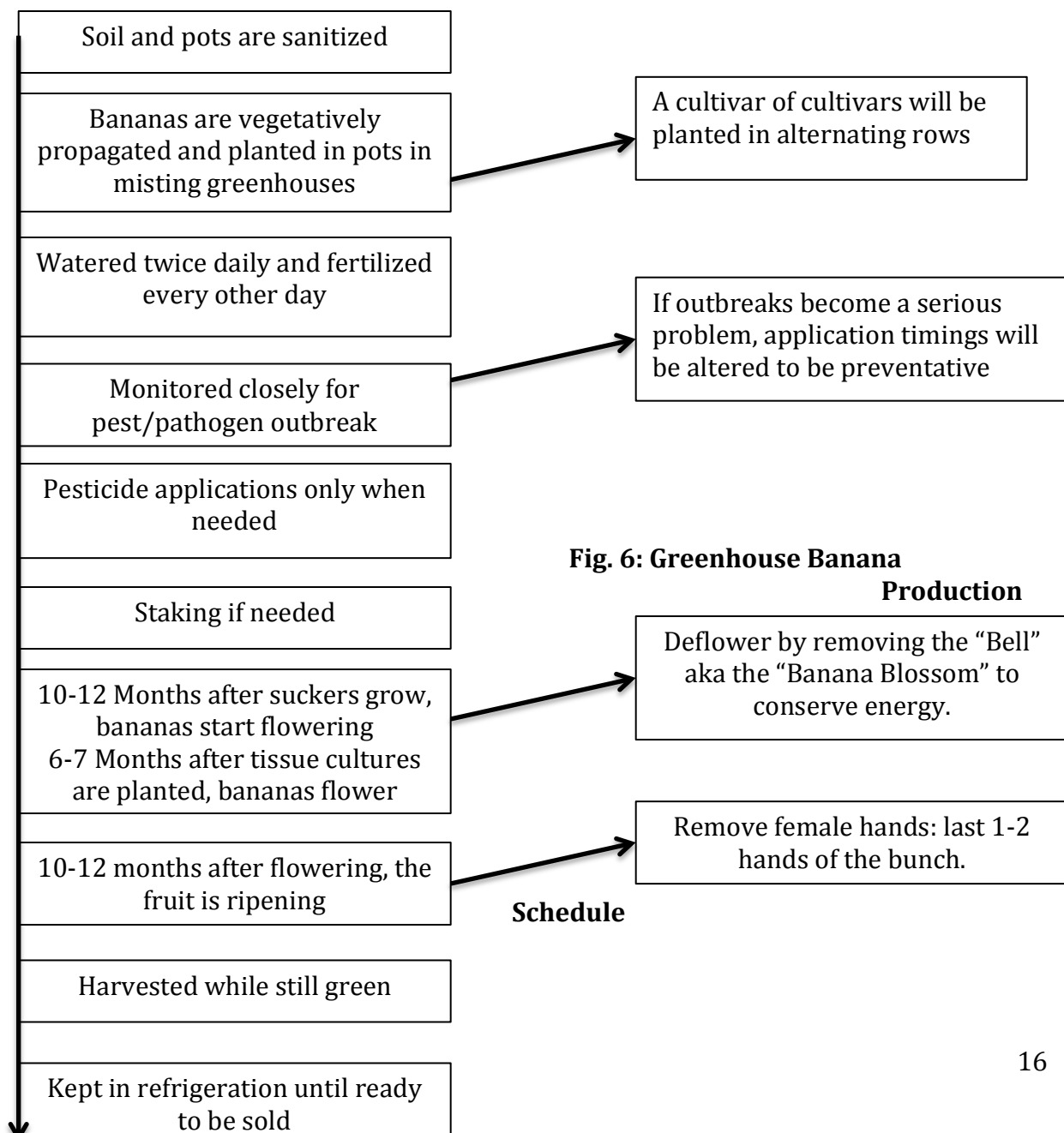
climates. The three cultivars that would be grown are 'Dwarf Cavendish,' 'Dwarf Red' and 'Dwarf Apple.' These are all cultivars that are currently grown on plantations and sold in supermarkets. They would be grown such that the rows alternate between the different cultivars. They could be grown in ground beds or containers. The pots could be air pruning to prevent root binding, although while first starting out, it might be best to experiment with different types to figure out the best pot. They should be planted in a soilless medium, e.g. ProMix, in 45 liter pots, which are suitable for plants up to 4 meters tall (AirPot).

Growing in greenhouses may also make it easier to monitor and control devastating pest/pathogen outbreaks. This will be done through sterilizing all soil and pots and ensuring all plant matter is sterile. There will also be daily scouting, which will be aided through the use of yellow sticky insect traps to help control and monitor aphids, thrips and a few other insects. These should be placed slightly above the plants and midway between the rows (Lindquist 1988). There should be a fog system in place in order to keep the humidity high as well as an irrigation system allowing the plants to be watered a minimum of once a day. As the plants get larger, they may need to be watered two or three times per day—scouting will be done to determine the proper amount of water. Also, as the plants get larger, they may be prone to tipping, so if necessary, they should be staked.

The amount of time until bloom and harvest won't be much different from plantation production—it will still be 16-18 months after planting to harvest. Since this is quite a long time, there should be some method of staggering the crops so that harvest can be continuous. For example, there could be a new round of plantings every 1-2 months. Harvest will also still have to be done by hand. The bananas will also have to be picked while still green and then refrigerated until they are ready to be sold. After harvest, the

vegetative parts of the plant will be composted and used in the soil for nutrients, and the pots and soil will be sanitized again.

From the greenhouse, they could be sold first at farmers markets and as part of a partnership with local CSA's (Community Supported Agriculture) in CSA boxes. Once fully established as a crop, they can then be sold to local restaurants and co-ops and eventually may work their way up to being sold in major grocery chain stores.





### **C. New Crop Ideotype**

One of the most major issues with the current banana production system is how susceptible they are to diseases. Many pesticides and fungicides are needed to maintain proper plant health. This is incredibly unsustainable and has a very negative effect on the environment. Part of this disease susceptibility has to do with the intense monoculture system, which is enforced by the demand of the single Cavendish cultivar.

Ideally, not only would bananas have better disease resistance, but there would also be several more equally desirable cultivars on the market. This would allow for easier intercropping in plantations, without the corporations taking an economic hit.

Intercropping would slow down the rate of the pathogens overtaking plant resistance. This, coupled with constant breeding efforts to maintain resistant cultivars, could potentially eliminate the threat of another cultivar going nearly extinct, like the 'Gros Michel'. And if one cultivar was to become completely overtaken by a pathogen, there would still be several other cultivars on the market for consumers to choose from.

While hopefully greenhouse production could help reduce instances of the deadly diseases, such as Panama Disease and Black Sigatoka, diseases can definitely still run rampant. Since large-scale banana production in greenhouses would be a new process, some experimentation in relation to fungicide applications and watering would be necessary. It would be ideal to keep everything sustainable and virtually chemical-free, but that is not always possible.

## Acknowledgements

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## References

Banana Market Review and Banana Statistics 2012-2013 [WWW Document], 2014. [WWW Document]. Food and Agricultural Organization. URL <http://www.fao.org/docrep/019/i3627e/i3627e.pdf> (accessed 15 Dec. 2015).

Banana Planters [WWW Document], n.d. [WWW Document]. Banana Planters Banana Cultivation Guide Comments. URL <http://www.bananaplanters.com/site/banana-cultivation-guide/> (accessed 15 Dec. 2015).

Air-Pot Original Archives - Air-Pot® [WWW Document], 2015. [WWW Document]. AirPot. URL <http://air-pot.com/garden/product-category/original-air-pot/> (accessed 15 Dec. 2015).

Bradtke, B., 2007. Growing Bananas - How To Grow Banana Plants And Keep Them Happy [WWW Document]. Growing Bananas - How To Grow Banana Plants And Keep Them Happy. URL <http://www.tropicalpermaculture.com/growing-bananas.html> (accessed 12.15).

Daden, J., Meier, E., Singh, V., Handeen, D., Rader, J., Schweser, G., 2013. Cold Climate Greenhouse Resource. CSBR. <http://www.extension.umn.edu/rsdp/community-and-local-food/production-resources/docs/cold-climate-greenhouse-resource.pdf> Accessed 15 Dec. 2015.

De Langhe, E., Vrydaghs, L., de Maret, P., Perrier, X., Denham, T., 2009. Why Bananas Matter: An introduction to the history of banana domestication. *Ethnobotany Research and Applications* 7.

Elfick, J., 2013. 15ADAD. School Science Lessons [WWW Document]. University of Queensland. URL [http://www.uq.edu.au/\\_school\\_science\\_lessons/51.13.1.gif](http://www.uq.edu.au/_school_science_lessons/51.13.1.gif) (accessed 15 Dec. 2015).

Evans, E., Ballen, F., 2012. Banana Market. *Food and Resource Economics* Vol. 43

Guarino, L., 2010. Where do bananas grow anyway? *Agricultural Biodiversity Weblog*. <http://agro.biodiver.se/2010/11/where-do-bananas-grow-anyway/> Accessed 15 Dec. 2015.

Hongwei, T., Liuqiang, Z., Riulin, X., Meifu, H., 2004. 22 Better Crops/Vol. 88 (2004, No. 4) Attaining High Yield and High Quality Banana Production in Guangxi. *Better Crops* 88.

Ilnyckyj, R., Holmes, D., Rickert, E. (Eds.), 2014. Banana Market. The State of Sustainability Initiatives Review .

Kepler, A. K. & F.G. Rust (in press), 2009. Living with Bananas in Hawai'i: Then & Now. University of Hawai'i Press.

Koeppel, D., 2010. 5 Banana Varieties. *Saveur* 129.

<http://www.saveur.com/article/Techniques/5-Banana-Varieties> Accessed 15 Dec. 2015.

Koeppel, D., 2008. Banana: The Fate of the Fruit That Changed the World. Penguin Group, New York, New York.

Lindquist, R., 1988. Use of Yellow Sticky Traps in Greenhouses. *Ornamentals Northwest Archives* 12, 15–15.

Morton, J., 1987. Fruits of Warm Climates. Miami, Fl.

Nsabimina, A., 2014. The local Nomenclature of the East African Highland bananas (*Musa AAA*) in Rwanda and its challenges, in: Anana Cultivar Names, Synonyms and Their Usage in East Africa. Bioversity International.

Ploetz, R., 2001. Black Sigatoka of Banana: The most important disease of a most important fruit [WWW Document]. APS. URL <http://www.apsnet.org> (accessed 15 Dec. 2015).

Vezina, A., Van den Bergh , I., 2015. Morphology of the banana plant [WWW Document]. ProMusa. URL [http://www.promusa.org/morphology of banana plant](http://www.promusa.org/morphology%20of%20banana%20plant) (accessed 15 Dec. 2015).

Workman, D., 2015. Bananas Exports by Country. World's Top Exports. <http://www.worldstopexports.com/bananas-exports-country/3363>. (Accessed 15 Dec. 2015).